FINAL REPORT

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ASTRONOMY

consisting of:

Measurements and Reductions

of Relative Positions of Double Stars

from Photographic Plates.

(Contract Nonr-548(00), NR 046 729)

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MEASUREMENTS AND REDUCTIONS OF RELATIVE POSITIONS OF DOUBLE STARS FROM PHOTOGRAPHIC PLATES

Introduction:

It has first been shown by Hertzsprung[1] that photographic observations of double stars have proven far superior in accuracy to the conventional visual observations.

Since the double star observations provide the fundamental measurements for the determinations of the masses of the stars, and since they may also allow the determination of other stellar characteristics, such as distance and central condensation, the higher accuracy of the photographic observations leads to more accurate determinations of these quantities.

The high accuracy of the photographic observations is also of special importance in determining whether apparent discordances in the observed orbital motions of certain nearby double star systems are caused by observational errors in the visual observations or by the existence of invisible companions in the systems.

Hertzsprung developed his method in 1914 and carried out a large observing program with the long focus refracting telescope of the Potsdam Observatory until 1919. The first large scale program of the same type following Hertzsprung's program was that of Strand[2] with the Sproul Observatory's large refracting telescope. The program was started in 1938 and continued to 1942, when it was interrupted by his war service. The program was resumed in 1946, using primarily the long focus refractor of the Dearborn Observatory, while additional plates were taken with the long focus telescopes of the Yerkes and Sproul Observatories.

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1) Publik. d. Astrophys. Obs. Potsdam, No. 75, 1920.
2) Strand, Astronomical Journal, v. 52, 1946.

The photographic method loses its accuracy if the separation of the images is less than 0.15 mm on the photographic plate, due to systematic errors arising from the interaction of the adjacent images upon each other, due to various photographic effects;[1] accordingly the lower limits set for binary stars included in the present program were 4".0 for the Dearborn refractor, 2".8 for the Sproul refractor, and 1".7 for the Yerkes refractor.

Description of the photographic method:

In order to obtain the high accuracy of the photographic method it is essential that the following factors are observed:

1). Nearly monochromatic light.

2). The effective ratio in light intensity between the components to be less than 1.6 (0.5 stellar magnitude).

3). Multiple exposures (40-60 images on one plate).

4). The plates measured on high precision measuring machines; allowing readings to one micron and with the periodic errors determined to the nearest 0.2 micron.

1). The nearly monochromatic light has been achieved by using visual refracting telescopes in combination with a yellow sensitive plate and a yellow filter.

The visual refracting telescope has the minimum focal length at 5500 Angstrom units in order to allow the rays most sensitive to the human eye to be focused without the disturbing effect of the adjacent extra-focal images formed by the red and blue wavelengths.

The photographic plates used in the program were Eastman spectroscopic plates of Class G. These plates have a strong sensitivity throughout the blue and green with a maximum at 5650Å, after which the sensitivity falls

1) [illegible], Annals of the Leiden Observatory, v. 18, p. 2, 1927.

off sharply. The blue sensitivity of the plates is absorbed by a yellow filter (Wratten Light Filter No. 12) which absorbs all light of wavelengths below 5000A.

2). The effective maximum ratio in light intensity of 1.6 between the components of observed binary systems has been achieved by using coarse gratings in front of the objective of the telescope for those pairs which have magnitude differences between the components larger than 0.5 magnitude. The gratings produce spectra placed symmetrically with respect to the central image. Since the light reaching the photographic plate is nearly monochromatic both first and second order images appear round. For binary systems where the difference in magnitude between the components is nearly one magnitude, a grating is placed in front of the objective giving a difference of one magnitude between central image and first order spectra. The mean position of the spectra is then used as the position of the center of the image formed by the brighter component, thus in effect reducing the magnitude difference between the components to zero.

For each of the three telescopes used in the present program four gratings were constructed producing respectively 1, 2, 3 and 4 magnitude differences in intensity between central image and first order spectra. These then allow the intensity difference between the components to be held below 0.5 magnitude for all binary systems with magnitude differences up to 4.5 magnitude.

3). In order to fully utilize the accuracy of the photographic method it is essential that approximately 30-60 images are exposed on each plate. Following this procedure, the accidental errors arising from anomalies in the atmospheric refraction ("seeing" effect), from displacements in the

photographic emulsion, as well as in the process of measurements, are cancelled out. Since the systematic errors arising from the same sources are small, the large number of exposures is essential.

While early in the present program the multiple exposures were obtained by manual operation of shutter and plateholder, this equipment was replaced at the Dearborn and Yerkes telescopes with new instrumentation, allowing automatic timing of the exposure as well as automatic shifts of the plates between the exposures.

The new equipment has increased considerably the quality of the images, because the manual operation of the previous equipment made it difficult to avoid vibrations in the telescope.

The plates were measured with the Gaertner high precision measuring machine at the Dearborn Observatory. Each machine has a screw with a one millimeter pitch, and for each screw the progressive and periodic errors have been determined to the nearest micron.

The exposures on each plate were measured in four positions of the plate leading to the measurement of the coordinates of the relative positions of the components in a rectangular coordinate system with the x-axis parallel to the celestial equator.

Statistics of Measurements:

At the completion of the present contract on August 31, 1953, the following data were available.

	Dearborn	Sproul	Yerkes	Total
Plates taken	825	165	168	1158
Plates measured	689	149	136	974
Total number of measurements	---	---	---	614,000

Of the total number of measurements, approximately 150,000 were made by the persons employed under the ONR contract. In addition final reductions were carried out for approximately 850 plates, of which the detailed results for 735 plates, comprising 410,000 settings, were prepared in manuscript form to be published in the Dearborn Annals Vol. 7, Part 1. The remaining results for 115 plates, which were completely reduced, are being retained for a future publication dealing with the orbital motion of the binary system 61 Cygni. Accurate photographic measures of this system by Strand have shown the existence of a dark component in the system with planetary mass of the order of 0.015 solar masses or 15 times the mass of Jupiter.[1] Extensive series of plates for this system are being continued for further check on this important system.

The detailed results of the measures and the accuracies which have been obtained have purposely been omitted from the present report, since they will be published in the Dearborn Annals, Volume 7, Part 1, scheduled for distribution by February 1954. This publication will be furnished to the agencies listed on the enclosure.

Acknowledgment:

The director of the project wishes to express his sincere thanks to the Office of Naval Research for its support. Without this support a serious delay would have occurred in completing the measurements, the reductions, and the preparation of the material for publication.

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1) Proceedings Amer. Phil. Soc., Vol. 86, 364, 1943.

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